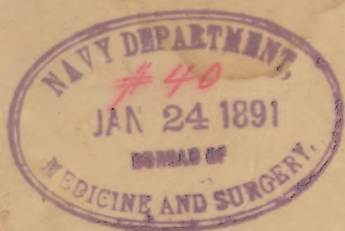


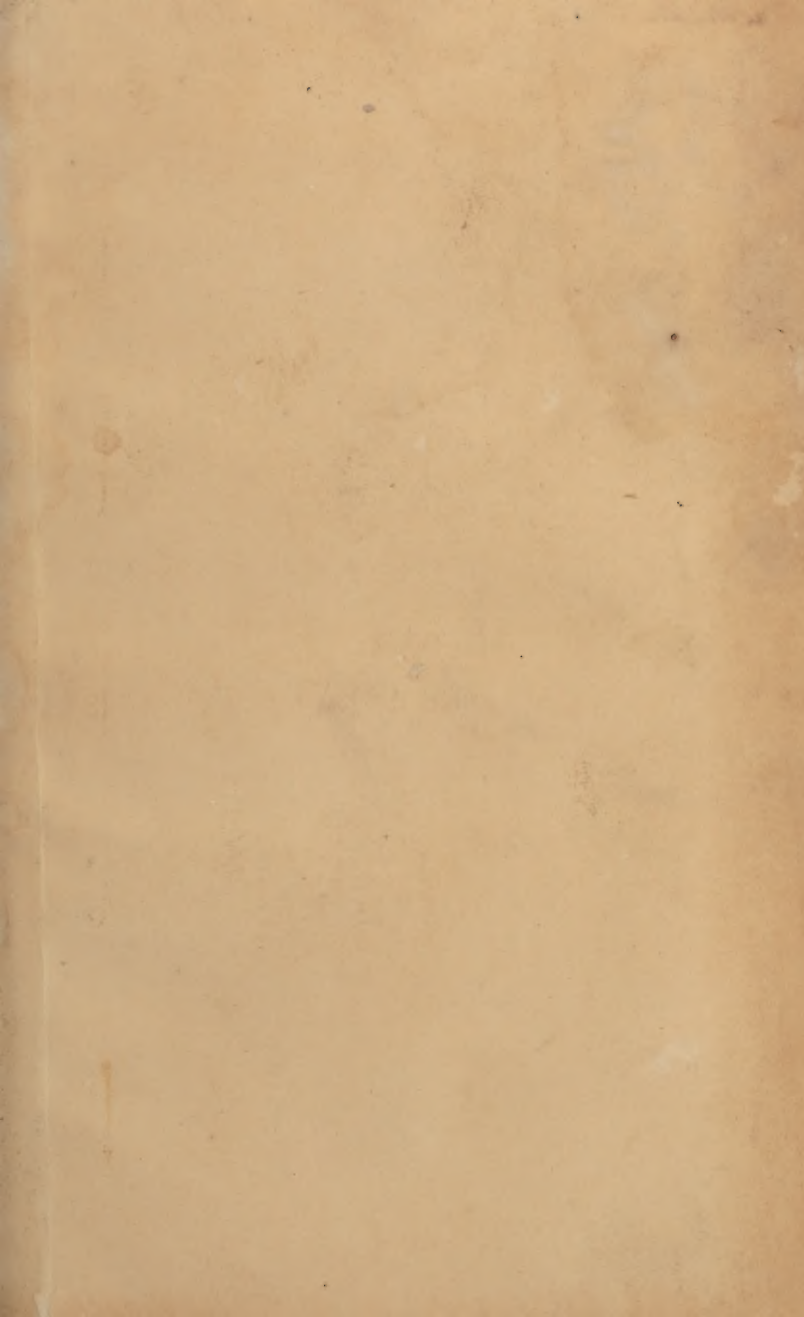
EXAMINATION
OF
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—
MASON.

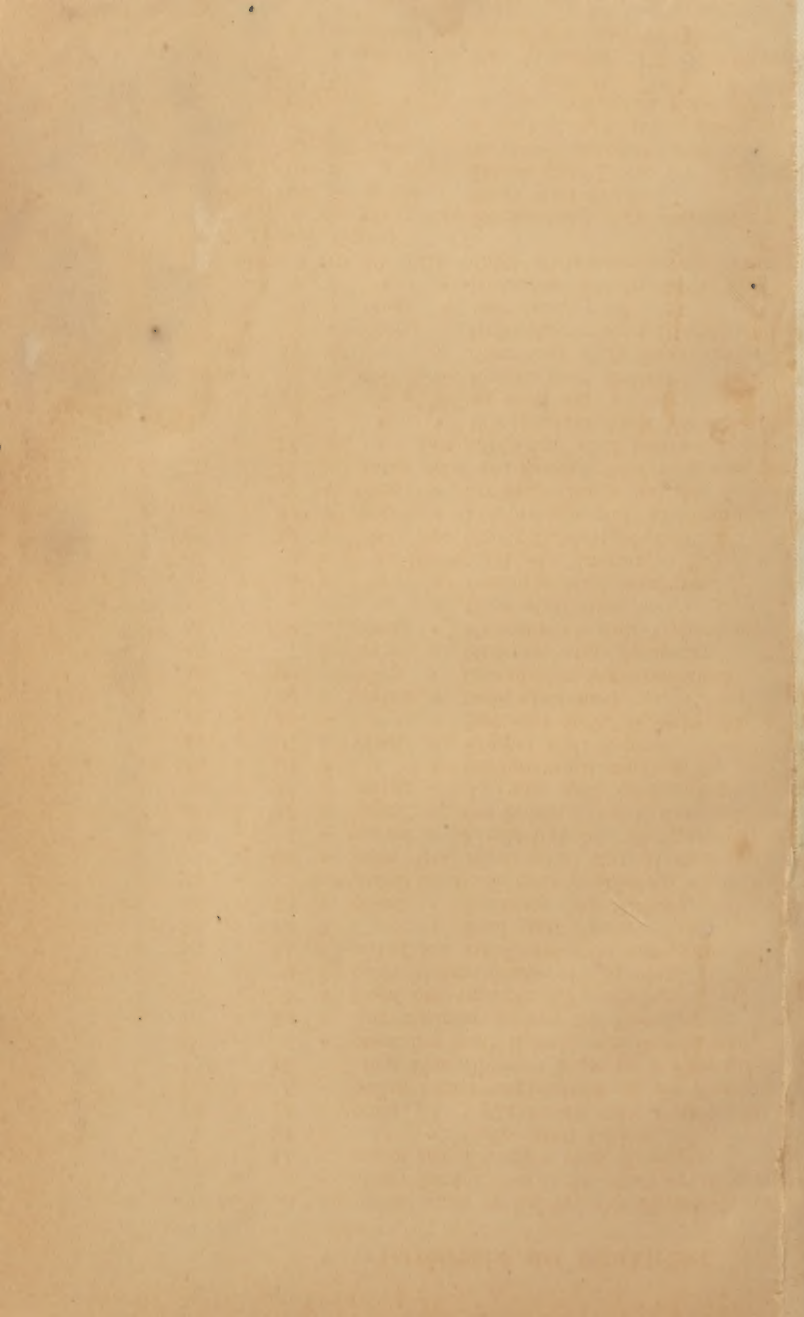




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EXAMINATION

OF

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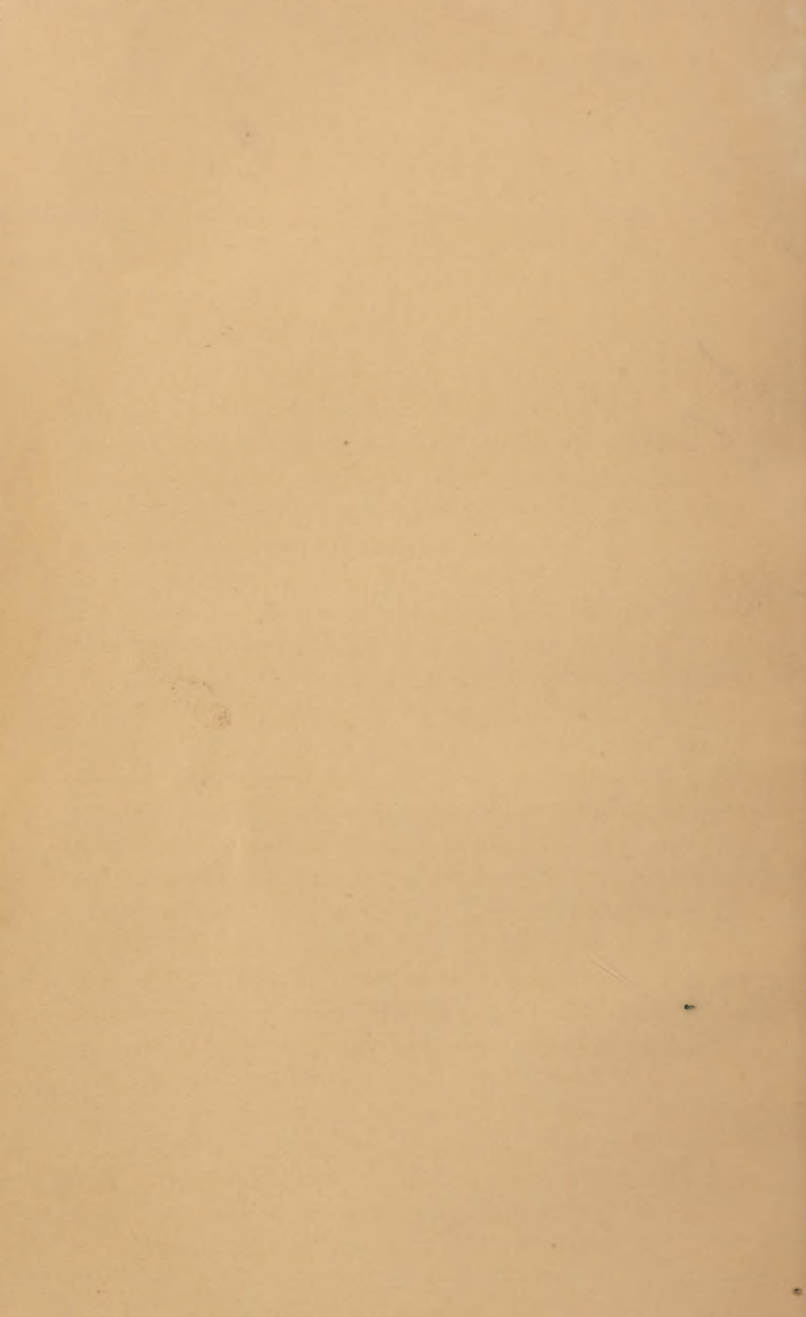
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PREFACE.

Although the following notes are issued in an entirely private manner, being arranged for use in the author's classes, yet, inasmuch as they may chance to fall into other hands, it may not be out of place to state why they were prepared. Many and excellent treatises already exist on water analysis, but even a casual observer must notice the great diversity of methods they formulate, upon a subject where uniformity is of prime importance. It was with a view to advance the cause of "uniformity" that the "water committee," of which the author is a member, was appointed by the chemical section of the American Association for Advancement of Science, at its Cleveland meeting in 1888. The preliminary report of the committee may be found in the *Journal of Analytical Chemistry*, vol. 3, page 398, and it is with a view of placing before the students of this institution, analytical methods based upon such report that these notes have been prepared.

RENSSELAER POLYTECHNIC INSTITUTE,
March 12th, 1890.



EXAMINATION OF POTABLE WATER.

However faithfully the various chemical tests may be applied to the question of the fitness or unfitness of a certain water for dietetic purposes, there is nothing upon which greater stress should be laid than a thorough, personal knowledge of the surroundings of the source of supply.

It has been held as a golden maxim by one of our authorities on water analysis, "never to pass judgment upon a water the history of which is not thoroughly known."

Each sample should be taken personally and its proper shipment superintended.

About three gallons will be found a convenient quantity to insure sufficiency in case of breakage of apparatus during work, and, where possible, glass stoppered green glass bottles are the proper vessels for storage. No attempt should be made to seal the stopper, it should fit tightly enough without that, but it is always well to tie it firmly in place with stout cloth, and, where sent by express, it would be safer to place a seal upon the fastening cord. The vessel, whatever it be, should be *new*, and should be rinsed two or three times with the water to be examined before it is finally filled. Never fill quite full, but leave a small space to

allow for possible expansion. If the sample be taken from a well, pump a few gallons before filling the bottle; if from a city faucet, let enough run to waste to empty the local lateral; if from a lake or stream, submerge the vessel about a foot, so as to avoid taking surface water.

Having secured the sample, begin the analysis at once, for reasons that will appear further on.

Hitherto no small confusion existed, on account of the many ways in which the results of water analyses were stated, but this difficulty, it is to be hoped, will be greatly done away with by the report of the committee of the American Association for the Advancement of Science, appointed to examine into this question.

The committee recommended that all results be given in *parts per million in weight*. This method has the advantage, that, a litre, or fraction thereof, of water, having been operated upon, and the substances found having been determined in milligrams, no long arithmetical calculations will be required.

Of course the assumption is made that a litre of water weighs a kilogram: a true enough statement for potable waters, but one capable of introducing error where mineral waters are dealt with, whose specific gravities are appreciably above unity. In such a case, the water is actually weighed, or else the weight is estimated from the known specific gravity and volume.

The water should not be filtered before analysis. If sediment be present it should be equally diffused by thorough shaking before measuring.

Total Solids.

Source: Material dissolved or suspended in water is naturally derived from the strata through which it passes, or the surface over which it flows. Thus are obtained waters of all degrees of hardness (see "Hardness") and of great variety of color and turbidity.

Determination:—Thoroughly shake the vessel containing the sample and then measure out 100 c. c. of the unfiltered water, by means of a pipette, into a weighed platinum dish.

Evaporate to dryness on the water bath, being careful to place a filter paper between the dish and the water in the bath, in order to prevent any deposit of impurities on the under side of the dish. (A better plan is to make use of a porcelain water-bath filled with distilled water). When dry, place the dish and contents in an air bath and maintain the temperature at 105° C for half an hour. Cool in a desiccator and weigh. Replace in the air-bath and repeat the weighing at intervals of half an hour until a constant weight be obtained. The final weight, less the known weight of the dish, will give the amount of total solids. This weight multiplied by ten will give the weight of solids per litre of water, which expressed in milligrams will represent parts per million.

It was formerly the custom to ignite this residue, moisten with carbonic acid water and again ignite and weigh. The loss in weight was reported as organic matter.

Concerning such treatment Tidy remarks: "It presupposes three things

- (a) That no organic matter is lost and none is gained during the evaporation of the water,
- (b) That all the organic matter is burned off by the ignition of a residue,
- (c) That nothing *but* organic matter is lost by ignition,

but in all these points the process fails."

It is unnecessary to further detail the fallacies of this exploded method, but it is important to note that while no quantitative results are to be expected from the ignition in question, yet considerable insight may often be obtained as to the character of the water, by observing the intensity of the charring and the presence or absence of fumes.

Dr. Angus Smith goes so far as to say: "It is remarkable what a clear insight is given into the quality of water by simply burning the residue. We can, by the eye and smell, detect humous or peaty acids, nitrogenous organic substances (smell of burnt feathers), and nitrates, and estimate their amount to a very useful point of accuracy."

Dr. Smart says: "The blackening during the process is of more interest than the mere loss of weight. No matter how few parts are lost, if the lining of the capsule blackens all over and the carbon is afterward dissipated with difficulty, the water is to be viewed as suspicious. What are called '*peaty*' waters, here constitute the exception." (*Report Nat. Board Health, 1880.*)

Dr. Smart conducted the ignition "at a gentle

heat, gradually attained," a rule to be followed in all cases. Angus Smith pointed out that "in waters containing nitrates and nitrites, no organic matter would be apparent on burning unless more should be present than these salts could oxidize," a fact always to be borne in mind.

(NOTE. So much difficulty is often experienced in weighing the "total residue," when the water contains hygroscopic salts, owing to the rapid absorption of moisture, that the author has of late substituted a large glass "weighing bottle" for the platinum dish in this determination. The bottle is constructed with a small stopcock in place of a handle on its cover, in order to permit introduction of air, and consequent easy removal of the cover after the weighing is completed. The vessel is used in the same manner as the platinum dish, but, being covered upon withdrawal from the air-bath, the weighing may be done at leisure. Another 100 c. c. of the water is quickly evaporated in platinum, and ignited, in order to observe the blackening of the residue, if there be any.)

Standards: As to the quantity of total solids that unpolluted water should contain, it would be well to note the following:

"Rivers Pollution Commission of Great Britain," gives as averages out of 589 samples analyzed for total solids:

Rain.....	29.5
Upland surface.	96.7
Deep well.....	432.8
Spring... ..	282.0

Dr. Smart (*Nat. Board of Health, 1880*):

Safe limit.	300.0
To be condemned.	1000.0

A. R. Leeds (*Water Depart. Wilmington, 1883*):

Standard for *American Rivers*..150. to 200.

Wanklyn regards as permissible 575.

NOTE.—It is indeed rare for water to be considered *too* pure, but in a recent paper on the Loch Katrine water, which supplies the city of Glasgow, it was proposed to effect the silicising of the water by bringing it in contact with red sandstone: thereby neutralizing its action on lead pipe, and checking any action it may have in producing infantile deformity, which many people, rightly or wrongly, ascribe to the use of this water. —[*J. Soc. Chem. Ind.* **5**, 649.]

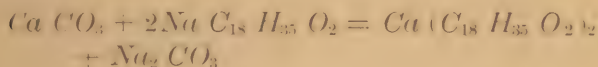
Hardness.

Before entering into the question of quantitative estimation, let it be premised here that “hardness” may be classified under two heads, viz.: “Permanent” and “Temporary.” The former is occasioned by the presence of calcium sulphate, and other soluble salts of calcium and magnesium, not carbonates, held in solution by the solvent action of the water itself; such a water cannot be materially softened by boiling under ordinary pressure.

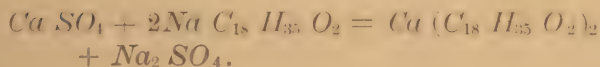
“Temporary” hardness is caused by carbonates of calcium and magnesium held in solution by carbonic acid present in the water. Boiling such a water expels the carbonic acid, whereupon the salts separate from solution.

Many samples of water possess both “permanent” and “temporary” hardness, and the analyst is at times called upon to report each separately; but more commonly the total hardness covers all that is required.

Ordinary hard soap is somewhat complex in structure, but for practical purposes we may consider it to consist of sodium stearate $Na (C_{18} H_{35} O_2)$. This salt coming in contact with the calcium carbonate or sulphate contained in a hard water, is immediately decomposed with formation of insoluble calcium stearate according to the following equations:



or



Of course none of the soap can be depended upon for detergent purposes until all the calcium salts present have been thus provided for, hence the enormous waste resulting from the use of some waters may readily be imagined.

Determination:—In undertaking the estimation of hardness, advantage is taken of the reaction above stated. A solution of soap of known

strength is prepared, and then poured into a given quantity of the water to be examined, until a permanent lather is formed, whereupon, from the known quantity of soap used, the amount of "hardening" salts present may be calculated.

The details are as follows :

Soap Solution :— From a new cake of Castile (Syria) soap, scrape ten grams of shavings. Dissolve them in one litre of dilute alcohol ($\frac{1}{3}$ water). If not clear, filter, and keep tightly stoppered.

Standardizing the Soap Solution : Carefully weigh out one gram of pure Ca CO_3 . Dissolve in a little HCl . Neutralize with a *slight* excess of $\text{NH}_4 \text{HO}$ and dilute to one litre. Each cubic centimetre of this solution will contain an amount of calcium salt equivalent to one milligram of Ca CO_3 .

Place 10 c. c. of this solution in an eight-ounce glass stoppered bottle, make the volume up to 100 c. with pure water and run in the prepared soap solution from a burette, little by little, (shaking after each addition,) until a lather be formed which persists for five minutes. Even when the amount of soap solution is approximately known, never add more than half a cubic centimetre at once, and never fail to shake after such addition. (See *Chem. News*, Aug. 1886.)

Note the amount of soap solution used. Now repeat the experiment, using 100 c. c. of pure water only (no calcium salt solution), and again note the amount of soap solution required. This second reading will give the amount of soap solution (no

inconsiderable quantity) used up by the 100 c. c. pure water, and by subtracting the same from the reading obtained in the first instance knowledge will be reached of the quantity of soap required for the calcium salt alone. Estimate now the value of 1 c. c. soap solution in terms of calcium carbonate and record the result on the bottle. Perhaps an example would be in keeping.

8.2 c. c. soap solution are required for 10 c. c.
 Ca CO_3 solution + 90 c. c. water

0.6 c. c. soap solution are required for 100 c. c.
 water.

Hence,

7.6 c. c. soap solution are required for 10 m. g.
 Ca CO_3 only.

Hence,

1 c. c. soap solution corresponds to 1.316 m. g.
 Ca CO_3 only.

Always place the date of standardizing on the bottle, and re-standardize frequently, as the soap solution is not permanent.

To take the hardness of a water: Place 100 c. c. in the eight-ounce bottle; run in the standard soap solution in the manner already stated, read off the amount required; multiply by the known value for 1 c. c. soap solution; multiply this again by ten, and then will be obtained the hardness expressed in so many parts of Ca CO_3 per million of water.

It was formerly customary to report hardness in "degrees" rather than parts per million, but the

difficulty of deciding which of the several systems of degrees was referred to, provoked so much confusion, that a change was made to the present simpler mode of expression.

Should a report of both temporary and permanent hardness be called for, the soap test must be made both before and after boiling.

If the hardness due to salts of magnesia be required separately, shake the water up with a little solid ammonium oxalate, filter off the precipitated calcium oxalate on a dry filter, and determine the hardness in the filtrate.

When a water is so hard as to require a greater amount of soap solution than suffices to saponify 23 *m. g.* Ca CO_3 , better results are obtained by diluting with an equal bulk (or more, if necessary) of pure water, inasmuch as too heavy a precipitate of the calcium stearate appears to interfere with the proper lathering. Of course the influence of the additional quantity of water must be allowed for.

Standards: The average hardness of good waters as given by the British "Rivers Pollution Commission" stands:

Rain.....	3.
Upland surface.....	54.
Deep well.....	250.
Spring	185.

Wanklyn allows..... 575.

Leed's standard for *American Rivers*..
 50 for soft, 150 for hard.

Chlorine.

Water is rarely found free from chlorine, yet, notwithstanding its almost constant presence, there is hardly a factor in the sum-total of water analysis towards which attention is more quickly turned, or regarding which there is closer scrutiny.

Excepting in unimportant instances, chlorine is always present in the form of common salt, washed from the air or soil, or added as one of the constituents of sewage. Salt itself is, of course, unobjectionable in the quantity usually present, but being, as it is, so largely used in our food, there is always warrant for suspecting sewage contamination where the figures for chlorine run high.

True it is that those figures are at times misleading, but they, like other data in water analysis, must be considered with judgment, and due weight be accorded the character of local surroundings.

Wanklyn, an eminent water authority, says: "I am of opinion that too much stress has been laid upon the chlorine in drinking-water, inasmuch as it is by no means rare to find an extensive quantity of chlorine in very pure water; and I know that, by reason of the chlorine, pure water has been condemned by water-analysts."

Opposed to this, Frankland (at least equally celebrated) says: "The condemnation of water, because it contains more than fifty parts of chlorine per million is rarely unmerited."

Determination: The determination of chlorine in water is extremely simple. It depends upon the

fact, that, if to a solution of a chloride, which has been colored yellow by addition of a few crystals of potassic chromate, a solution of silver nitrate be added, white silver chloride will be produced until the last trace of chlorine be disposed of, whereupon red silver chromate will begin to appear.

The *Standard Silver Solution* is prepared by dissolving 4.8022 grams of crystallized silver nitrate in one litre of water. Each cubic centimeter of such a solution is of a strength sufficient to precipitate one milligram of chlorine.

One hundred c. c. of the water to be examined are placed in a porcelain dish; just enough potassic chromate is added to give a distinct yellow color, and then the standard silver solution is run in from a burette until the red tint of the silver chromate just appears. From the known amount of silver solution used, the amount of chlorine present is obtained, and this, multiplied by ten, will give the chlorine in milligrams per litre or parts per million.

For the sake of accuracy it is better, during the titration, to have a second dish of water also colored with potassic chromate, in order that the formation of the red tint in the dish operated upon, may, by contrast, be more readily detected.

For determination of chlorine in any sample of potable water, likely to be encountered, the above process is abundantly accurate, but should the analysis of sewage be contemplated, it would be better to abandon volumetric methods entirely, and weigh the silver chloride precipitate directly.

Standards :—The “ Rivers Pollution Commission ” reports the average amount of chlorine in 589 samples of unpolluted water as follows :

Rain.....	8.22
Upland surface.	11.3
Deep well.....	51.1
Spring.....	24.9

Wanklyn considers 140. as possibly suspicious.

Frankland considers the permissible limit as 50.

Leed's standard for *American Rivers*, 3. to 10.

Ordinary sewage about 110 to 160.

Human urine contains about 5000.

NOTE. — “ The amount of chlorides in the rain is nearly always greater in the winter months than in the summer months. An abnormal amount of chlorides can generally be traced to storms from the southwest of England bringing salt spray from the Bristol Channel, about thirty-five miles distant. Crystals of common salt have been found after such storms on the windows of the college facing west. On one occasion, in September, 1867, Professor Church found chlorine equivalent to 6.71 grains of common salt per gallon (69.7 parts per million of chlorine) in storm water.”—(*Chem. News, Dec. 10, 1886.*)

Prof. Kinch reports the average amount of chlorine in the rain-water collected at Cirencester, England, during a period of twelve years to be 3.36 parts per million.”—(*Chem. News, Dec. 10, 1886.*)

Nitrogen as Nitrites.

Frankland writes: "When fresh sewage is added to water already containing nitrates, the latter are generally reduced to nitrites," and it may be there are none to disagree; but when he adds that, "when nitrites occur in shallow wells or river waters, it is highly probable that these waters have been very recently contaminated with sewage," thereupon Wanklyn declares that "nitrates and nitrites have been erroneously regarded as measuring the defilement of water." Finally, in the report of the National Board of Health for 1882, Mallet concludes: "With the facts of this investigation before me, I am inclined to attach special and very great importance to the careful determination of the nitrites and nitrates in water, to be used for drinking."

Let us regard Mallet's statement as conclusive. It is based on most carefully conceived and executed experiments which "point strongly to the production of nitrites by oxidation of organic nitrogen and their subsequent conversion into nitrates by further process of oxidation."

Whether, therefore, the presence of nitrites be considered due to reduction of preëxisting nitrates by organic matter, or caused by direct oxidation of organic nitrogen, it becomes a necessity to estimate their quantity, for in either case the initial cause is **probably contamination.**

Determination :—Of the several methods of late used for the determination of nitrites, the second

one suggested by Griess seems to be the most deserving of favor. It depends, in principle, upon the red coloration ("azobenzolnaphthylamine sulphonic acid") produced whenever "sulphanilic acid" and "naphthylamine hydrochloride" are added to an acidified solution of nitrite. The test is exceedingly delicate and is capable of distinguishing one part of nitrogen as nitrous acid in one thousand million parts of water.

The reagents are prepared as follows:

Sulphanilic Acid:—Dissolve 1 gram of the salt in 100 c. c. hot water. The solution keeps well.

Naphthylamine Hydrochloride:—Boil $\frac{1}{2}$ gram of the salt with 100 c. c. water for ten minutes, keeping volume constant. Place in glass stoppered bottle and add a little pulverized carbon to decolorize the solution. It tends to grow slightly pink on standing, but not sufficiently so to interfere with its use. Filter from carbon when required for use.

Standard Solution of Sodium Nitrite:—Sodium nitrite may be bought, but its purity is always to be questioned, and moreover it is too deliquescent a salt to be weighed with ease and accuracy. It is better, therefore, to prepare the silver salt, which may be readily handled, and from it the solution required may be made.

To a cold solution of commercial sodium or potassium nitrite add a solution of silver nitrate as long as a precipitate appears. Decant the liquid and thoroughly wash the precipitate twice with cold water. Dissolve in boiling water. Concen-

trate and crystallize the silver nitrite from the hot solution. Dry in the dark at the ordinary temperature (using vacuum is better) and keep for use.

Weigh out .22 gram of the dry silver nitrite. Dissolve in hot water. Decompose with slight excess of sodium chloride, cool, if necessary, and dilute to one litre. Allow the precipitated silver chloride to settle, remove 5 c. c. of the clear solution and dilute the same to one litre. This second dilution (which is the standard solution to be used) will contain an amount of nitrite per cubic centimetre, equivalent to .0001 milligram of nitrogen.*

In order to undertake the determination of nitrites, place 100 c. c. of the water to be examined in a "Nessler" jar. Acidify with one† drop concentrated *HCl*. Add 1 c. c. of the sulphanilic acid solution, followed by 1 c. c. of the solution of hydrochloride of naphthylamine; mix; cover with watch glass and set aside for thirty minutes. Prepare at the same time other "Nessler" jars, containing known amounts of the standard solution of sodic nitrite and diluted to the 100 c. c. mark with *pure* distilled water (see page 28); adding the reagents as above. At the end of the time stated (thirty minutes) examine the depth of the pink

*The standard solution here advocated is much weaker than the one recommended by the committee, the latter being undoubtedly too strong for convenient use. The committee's solution contained .01 *m. g.* nitrogen, as nitrite, per cubic centimetre.

†Addition of too much acid might cause *nitrates* to react as well.—[*Analyst* 12, 51.]

color formed, and, by comparing the unknown with the known, an accurate determination of the amount of nitrogen present as nitrites may be made.

Standards.:—In a report upon the presence of nitrites in eighteen “natural waters, believed from actual use to be of good, wholesome character,” and collected from every variety of source, Mallet’s determination show an average of .0135 part nitrogen as nitrites per million parts of water. The average, by the same investigator, for nineteen waters “which there seems to be fair ground for believing have actually caused disease,” is .0403 part per million.

In this connection, however, it would be well to bear in mind Frankland’s statement, that “the presence of these salts in *spring* and *deep well* water is absolutely without significance: for, although they are in these cases generated by the deoxidation of nitrates, this deoxidation is brought about either by the action of reducing mineral substances, such as ferrous oxide, or by that of organic matter which has either been embedded for ages, or, if dissolved in the water, has been subjected to exhaustive filtration.” This is merely another instance of how careful the analyst should be to become familiar with the source of the water before undertaking to pass judgment upon its quality.

The *absence* of nitrites, moreover, proves nothing. I have recently had a most foul cistern water for analysis, which showed but a trace of nitrites

and no nitrates, and yet the water was contaminated with the *entire house drainage*, and produced most serious illness.

Leed's standard for *American Rivers*, 0.003

See page 15 Vol 61-1890
Chem. News.

Nitrogen as Nitrates.

Taking Mallet's statement as final, that there is every reason for assuming that nitrates present in water may be but the further step in the oxidation of nitrogenous organic matter, it necessarily becomes important to obtain an estimate of this constituent, which, in Frankland's opinion, is a factor in the measurement of "previous sewage contamination."

The value of such determination may be further accentuated, upon noting what Dr. Bartley, president of the "American Society of Public Analysts," found, to his surprise, that well water, contaminated with drainage from cow stables, had, in several instances, shown little or no free nor albuminoid ammonia (Wanklyn's measures of contaminations), although large amounts of nitrites and nitrates were detected.

By allowing acidified water to be acted upon by the copper-zinc couple, any nitrite or nitrate present will be reduced to a salt of ammonia, and may then be determined by "Nesslerizing." The subtraction of the already determined nitrites permits the fixing of the value for nitrates.

The copper-zinc couple is prepared by taking a

piece of sheet zinc (four by six inches), rolling the same into a loose coil, and immersing it in a 1.5 per cent. copper sulphate solution, until its surface is well covered with a continuous layer of the black copper. The roll should be then lifted out, carefully rinsed with pure water and used without delay.

Determination:—Make 500 c. c. of the water to be examined distinctly acid with oxalic acid, added in fine powder, and pour half of it into each of two wide-mouthed, glass-stoppered salt bottles, of about 400. c. c. capacity. Into *one* of these bottles place, also, the copper-zinc couple prepared as above. Stopper the bottles and leave them in a warm place for twenty-four hours.

Gently agitate the liquid in the bottle containing the copper-zinc couple and let the deposit settle again. Remove 50 c. c. from each bottle and “Nesslerize,” using 4 c. c. of “Nessler solution” (see *Free Ammonia*). The difference between the two readings will give the amount of ammonia due to the reduction of the “nitrites” and “nitrates” present. The previously determined “nitrites” must be, of course, subtracted.

The amount of ammonia produced by the copper-zinc couple may often be so large that only 5 or 10 c. c. can be taken for each test, the volume of 50 c. c., required for “Nesslerizing,” being made up with pure water.

Standards:—Referring again to Mallet’s report before quoted, we find a very marked difference between the average amount of nitrates present in

good, as compared with the quantity found in bad waters.

In thirteen samples of water "known to be pure" the nitrogen present as nitrates averaged 0.42 (the extreme limits being 0.00 and 1.04), while in twenty samples of water believed to be objectionable, the average figures run as high as 7.239 (the extreme limits being 0.00 and 28.403). Such a difference justifies Mallet's statement that he regards the determination of nitrates as of great importance. (*See Report Nat. Board of Health, 1882.*)

Ekin :—(dangerously polluted if in ex-	
cess of)	6.00
Vienna Commission allows.....	1.04
Hanover " "	2.60
Brandes " "	7.00
Fischer (<i>Jour. für Prakt. Chem.</i>)... ..	7.00
Leed's standard for <i>American Rivers</i> .	
..... ..	1.11 to 3.89

The Rivers Pollution Commission give the following averages from 589 unpolluted waters for nitrogen as nitrites and nitrates *together* :

Rain.....	0.03
Upland surface.....	0.09
Deep well.....	4.95
Spring.....	3.83

NOTE.—Fresh sewage is often found entirely free of either nitrites or nitrates simply because the organic nitrogen present has, as yet, not had sufficient opportunity to become oxidized thereto (see page 21).

ORGANIC MATTER.

A revolution has been worked during recent years in the determination of organic matter in potable water. Methods have arisen and disappeared. Authors of the highest rank have combatted each other in print, with a success in establishing their views that has not always been commensurate with their positiveness in stating them.

It was in effort to throw a little unprejudiced light upon the several processes of rival writers, that Mallet undertook the investigation, from the report of which we here so often quote : an investigation that required a period of years for its accomplishment, and which marks an era in the history of water analysis. As therein referred to, there are three methods of estimating organic pollution, worthy of special mention, viz.:

- (a) The Combustion process of Frankland.
- (b) The Albuminoid Ammonia process of Wanklyn.
- (c) The "Forschhammer" process, as modified by subsequent investigators.

Concerning the first, which is a direct combustion of a water residue, after the manner of an ultimate organic analysis, we note the following in the "Analyst" for September, 1885: "It is subject to many causes of error, and is of so extremely

delicate a nature as to be almost abandoned at the present time." In his report to the Phila. Water Board for 1884, Dr. Leeds, referring to this method, says: "The determinations were discontinued, because the amount of information which they afforded did not appear commensurate with the great labor which they involved."

Speaking of the method, Mallet says: "It cannot be taken up off-hand, and even tolerable results obtained at once. From the hands of a person without proper laboratory training, its results are utterly valueless. It is hence better adapted to regular use in a large public laboratory than to occasional use by a private individual in now and then examining a single water."

In short, Frankland's combustion method is difficult, liable to error in unpracticed hands, and its results are not indispensable for forming a correct opinion of the sanitary value of a water.

A far more general method for obtaining information as to organic impurity, is Wanklyn's

Albuminoid Ammonia Process.

In the employment of this method a knowledge of the amount "*Free Ammonia*" present is also obtained.

We may outline the process as follows: The "*Free Ammonia*" is distilled from a measured quantity of the water and its amount determined by what is known as "*Nessler's*" method (to be described later). Strongly alkaline solution of

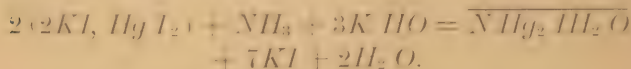
potassic permanganate is then added to another portion of the water and the distillation repeated. Nitrogenous organic matters are thereby broken up and the resulting ammonia ("Albuminoid"), which distills over with the steam, is determined by the "Nessler" method, in like manner as before. It must be noted that the so-called "Albuminoid" ammonia does not exist ready formed in the water; but is a product of the decomposition of organic nitrogenous substances by the alkaline permanganate. The term is derived from the fact that "Albumen" gives off ammonia, in like manner, when similarly treated.

The reagents necessary are :

"Nessler's" Solution :—Dissolve 16 grams mercuric chloride ($Hg Cl_2$) in about half a litre of pure water. Dissolve 35 grams potassic iodide (KI) in about 200 c. c. pure water. Pour the first solution into the second, until a faint show of excess is indicated. Add 160 grams solid potassium hydrate (KHO). Dilute to one litre and finally add strong solution of mercuric chloride, little by little, until the red mercuric iodide ($Hg I_2$) just begins to be permanent. Do not filter from excess of mercuric iodide, but let the same settle to the bottom of the vessel. The finished reagent should have a pale straw color.

"Nessler's" solution will give a distinct brownish-yellow coloration with the most minute traces of ammonia or ammonium salts. If the quantity of ammonia be at all considerable a brown precipitate

will appear. The reaction in case of either precipitate or coloration will be



Pure Water :— This must be prepared with great care, in a room free from the usual laboratory fumes. In short, the entire examination of potable water should be undertaken in a locality other than a general working laboratory. Fit a two gallon retort to a large Liebig condenser, fill with good spring water, distill; collect distillate in 50 c. c. "Nessler" jars and to each successive jarful so collected, add 2 c. c. "Nessler" solution and mix. After waiting five minutes, should a brown tint be observed upon looking through the liquid *longitudinally* at a white porcelain tile, or piece of white paper, the presence of ammonia is indicated.

Continue the distillation and the "Nesslerizing" of the successive 50 c. c. portions of the distillate until no coloration is obtained even after standing for five minutes. While waiting the said five minutes, protect the liquid from the action of the air by covering the jar with a watch glass. When ammonia ceases to be detected, the distilled water may be collected for use. The distillation should not be pushed too far, both on account of danger to the retort and of possible production of ammonia, from decomposition of the organic material remaining in the bottom. In this laboratory we have for some time made use of a two-gallon copper retort with tin worm; and find it

most satisfactory for the preparation of ammonia-free water. There is no objection to its use, provided it be carefully looked after, so as to prevent any approach to dryness.

Alkaline Potassic Permanganate:—Dissolve 200 grams solid potassium hydrate (KHO) and 8 grams crystallized potassic permanganate ($K_2Mn_2O_8$) in 1250 *c. c.* of pure water. Boil down to one litre and keep for use.

Sodium Carbonate Solution:—Prepare a saturated solution of the recently ignited (not fused) salt, in ammonia-free water.

Standard Ammonia Solution:—Dissolve 1.5706 grams of pure, dry ammonium chloride in half a litre *pure* water. Dilute 5 *c. c.* of this solution to half a litre with *pure* water. This second solution will represent a strength of .01 *m. g.* of NH_3 per cubic centimeter, and is the standard solution used.

Determination of Free Ammonia.

Fit a one-quart, glass, tubulated retort to a large Liebig condenser,* letting the neck of the retort pass well into the condensing tube (3 or 4 *c. m.*) and making the connection with a piece of large size soft rubber tubing. This connection must be thoroughly tight (see page 37). Place 200 *c. c.* *pure* water in the retort, and add 10 *c. c.* of the sodium carbonate solution. Distill off two 50 *c. c.* jarsful

*The one used in this laboratory has a brass barrel 36 by 2 $\frac{3}{4}$ inches. The interior glass tube is 54 by $\frac{5}{8}$ inches and is tapered at one end to enter the "Nessler jar."

of water, and "Nesslerize" the second in order to be sure that no ammonia yet remains in the retort. Any ammonia that may have resulted from the imperfect cleaning of the apparatus or that may have been present in the sodium carbonate solution, will usually all go over in the first 50 c. c., but the same quantity (*i. e.*, 100 c. c.) must be distilled off in all cases, in order that when the actual analysis of the unknown water is started upon, the condition as to volume may be always constant.

In fact it may be conveniently stated here, that *perfect uniformity of conditions*, is a requisite for **success in water analysis**.

To the contents of the retort is now added half a litre of the water to be examined.

Distill and catch the distillate in 50 c. c. "Nessler" jars. The rate of the distillation should be so managed as to allow about ten minutes for the filling of each 50 c. c. jar. Add 2 c. c. "Nessler" reagent to each jarful and continue the operation with each successive portion of the distillate, until no further reaction for ammonia is apparent after waiting five minutes. Usually four jarsful will be sufficient to carry off all free ammonia. From a burette, measure definite amounts of the *Standard Ammonia Solution* into several clean "Nessler" jars. Dilute each to the 50 c. c. mark with pure water: add 2 c. c. "Nesler" solution, mix,* and,

*The most convenient mixer for use with "Nessler jars" is a glass rod having two glass cross-pieces fused on to it at one end. Such a rod will mix the reagent and distillate very thoroughly if simply moved up and down a few times in the tube.

after standing for five minutes, compare as to depth of tint with the distillates already "Nesslerized." With a little practice it will be found easy by varying the amounts of standard ammonia solution used, to produce colors corresponding to those existing in the distillates, and thereby a most accurate knowledge of the quantity of ammonia actually present may be obtained. Such ammonia existed ready formed in the water, either free or as an ammonium salt, and passed over unchanged with the steam; it is, therefore, technically known as "*Free Ammonia*."

To make clear the calculation of results, let us cite an example: Suppose the first jarful to have required 9 *c. c.* standard ammonia solution (diluted to 50 *c. c.*) to match its color when "Nesslerized;" the second one 3 *c. c.* and the third 1 *c. c.* Then, since each *c. c.* of the standard ammonia solution corresponds to .01 *m. g.* NH_3 , the whole amount of "Free Ammonia" present in the original half litre of water would be:

109
203
301
400

.13 *m. g.*

Multiplying this by two, to obtain the quantity for an entire litre, and remembering that 1 *m. g.* is the millionth part by weight of a litre of water, we find the total "Free Ammonia" present in the water to be 0.26 *part per million*.

Albuminoid Ammonia.

Throw out the residue remaining after the distillation for *Free Ammonia*, rinse the retort thoroughly, and refit it to the condenser. Place in the retort 200 *c. c.* pure water and 50 *c. c.* of the alkaline permanganate solution. Distill off three 50 *c. c.* jarsful, and "Nesslerize" the third one in order to ensure freedom from ammonia. Add half a litre of the water under examination, and proceed with the distillation, and the "Nesslerizing" of the successive 50 *c. c.* portions of the distillate, as in the determination of *Free Ammonia*. The distillation is to be continued as long as compatible with the safety of the retort, unless the ammonia should sooner cease to be evolved. The ammonia determined by this distillation will be "*total*" (*i. e.*, "*Free*" plus "*Albuminoid*"), therefore from the Nessler reading of each jarful of distillate must be subtracted the reading for the corresponding jarful for "*Free Ammonia*," the difference will give the "*Albuminoid Ammonia*."

The calculation is entirely similar to that for *Free Ammonia*, as stated.

ALTERNATE METHOD FOR "*Free*" AND "*Albuminoid*" AMMONIA.

"In view of the apparently very general character in this country of taking 500 *c. c.* of water for the analysis, the committee did not deem it wise to recommend, now, the taking of 100 *c. c.*, notwithstanding that to several of its members this latter method seemed more desirable."

The retort and condenser employed are, of course, smaller and

the Nessler jars hold 40 c. c. instead of 50 c. c. The quantities operated with are as follows :

Forty c. c. pure water and 2 c. c. sodium carbonate solution are placed in the retort, distilled, and two jarsful of distillate caught and "Nesslerized," as before, to ensure freedom from ammonia.

One hundred c. c. of the water to be examined are then introduced, and the distillation maintained at the rate of a jarful every *two* minutes.

For "*Albuminoid Ammonia*," 40 c. c. of pure water and 10 c. c. alkaline permanganate solution are distilled, and three jarsful of distillate caught, the *third* being Nesslerized as in other method.

One hundred c. c. of the water are then added and the albuminoid ammonia determined as before described.

Use $\frac{1}{2}$ c. c. "Nessler reagent" for "Nesslerizing."

Interpretation of Results:—Concerning the interpretation of results, Wanklyn, the inventor of the method, is very dogmatic, and says: "The analytical characters as brought out by the ammonia process, are very distinctive of good and bad waters, and are quite unmistakable. There is, indeed, hardly any branch of chemical analysis in which the operator is less exposed to the risk of failure." This statement is altogether too strong. Waters of great organic purity, or those of great pollution, are undoubtedly easy to classify, but with the great mass of cases which lie about the boundary line between "good" and "bad," the greatest care is to be exercised in the reading of results and the passing of judgment. One rule, already mentioned, and upon which too much stress cannot be laid, is never to give an opinion concerning a water whose history and surroundings are not thoroughly known.

It is exceedingly unfair to demand of the chemist

a report as to the character of a water upon the merits of the analysis alone, for a water analysis is strictly *not* an analysis properly so called: but a series of experiments conducted as an aid to judgment.

An interesting case came to this laboratory shortly since. Water derived from the melting of pure artificial ice was shipped here from Florida, and, upon distilling the same for "Free Ammonia," the enormous quantity of 1.18 part per million was found. The ice having been exposed to the ammoniacal atmosphere of the freezing house during melting for shipment, of course, absorbed ammonia, and thus the high figures were accounted for. Without the attached history, any analyst would have immediately condemned the water as being "grossly contaminated," and would have been justified in so doing.

The "Free Ammonia" in artesian wells is often excessive, under circumstances that make animal contamination an impossibility, and even rain water, freshly collected after periods of long drouth, will often exhibit properties calculated to mislead the analyst.

C. B. Fox gives the following determinations in pure *deep well* water.

	Free Ammonia.	Albuminoid Ammonia.
Well 230 feet deep	0.80	0.05
" 250 " "	0.76	0.04
" 300 " "	0.74	0.03
" 330 " "	0.37	0.06
" 385 " "	0.59	0.04
" "very deep"	0.41	0.07

This excess of free ammonia may be due either—

“1° To entrance of rain water.

“2° To the beneficial transformation of harmful organic matter into the harmless ammonia, through the agency of sand, clay, and other substances, which act on the water in a manner similar to the action of a good filter.

“3° To some salt of ammonia existing in the strata through which the water rises; or,

“4° To the decomposition of nitrates in the pipes of the well. Mr. H. Slater suggests that the agent concerned in this reduction may, in the case of the deep well waters, be the sulphide of iron which is found in the clay.

“We conclude, then, that the presence of free ammonia in such comparatively large quantities in these deep well waters is due to the reduction of nitrates and nitrites by sulphide of iron, or some kinds of organic matter, or some other agent; such oxidized nitrogen salts having been produced in past ages by the oxidation of organic matter.”—*For, Sanitary Examinations of Water, Air and Food.*

Wanklyn would clear away all difficulty of interpretation by holding that “Albuminoid ammonia above .10 part per million begins to be a very suspicious sign; and over .15 it ought to condemn a water absolutely.” Yet that such a hard and fast rule is too severe for general application may be seen from the fact: “That the waters of the purest mountain streams in our unsettled West,

evolution indicates that the organic matter is in a putrescent or decomposing condition."

Thus we see that the reading of results is entirely a question of opinion and sound judgment, and in this connection Mallet's conclusion cannot be read without marked interest; he says: "It is impossible to decide absolutely upon the wholesomeness or unwholesomeness of a drinking water by the mere use of any of the processes for the estimation of organic matter or its constituents. I would even go further, and say that, in judging the sanitary character of a water, not only must such processes be used in connection with the investigation of other evidence of a more general sort, as to the source and history of the water, but should even be deemed of secondary importance in weighing the reasons for accepting or rejecting a water not manifestly unfit for drinking on other grounds. There are no sound grounds on which to establish such general standards of purity as have been proposed."

In working the "Albuminoid Ammonia" process, it is of importance that sundry minor details should be observed in order that concordant results may be obtained; attention is therefore called to the following points:

- 1° Use a tubulated glass-stoppered retort, and connect the same with the condenser by large bore, soft rubber tubing. The retort neck should project 3 to 4 *c. m.* into the condenser tube, and the rubber be drawn over both so as to make a perfectly tight

joint.* Particularly avoid the paper packing recommended by Wanklyn, as the same cannot but lead to loss of ammonia.

2° Keep the current of cooling water passing through the condenser at a velocity such that the difference between the temperature of the inflowing and outflowing water shall not exceed one degree centigrade.

3° Even with the utmost precaution some ammonia will be lost through imperfect condensation. Dr. Smart found that "the varying percentages of loss may be taken as representing the heating power of the flame used, or, inversely, the time occupied in distillation." Varying his time from eight minutes to half an hour, for that required to fill a 50 c. c. "Nessler" jar, he found a loss varying from $12\frac{1}{2}$ to 2 per cent. and giving an average of 7.2 per cent. The amount of ammonia being therefore a function of the time employed, it becomes necessary to eliminate, so far as may be, any error that might arise from this source, by conducting all distillations as nearly as possible at the same rate. So manage the lamp, therefore, as to fix the time required for the distillation of 50 c. c. at ten minutes.

* Trouble is often experienced with certain waters, owing to their tendency to "bump," and thus permit of a portion of the retort contents being mechanically carried over into the condenser tube. We avoid this difficulty by bending the neck of the retort through an angle of about twenty degrees, at a point a little beyond its middle. Upon fitting such a bent retort to the condenser, the contained liquid rests well towards the back, and splashing over is practically impossible.

4 It is not sufficient to note the *total* amount of "Free" and "Albuminoid Ammonia," but the full notes of the "Nesslerizing" process must be retained, that the *rate* at which the ammonia passes over may be determined. As before stated, important findings may be deduced therefrom. Dr. Smart believes "that a water which in the third or fourth measure of its distillation gives a persistent evolution of 'Free Ammonia,' which is followed in the progress of the experiment by a persistence of twice that quantity of 'Albuminoid Ammonia' probably contains *urea*." He is, as the result of investigation, led to add, that a water which yields such results will contain "as many parts per million of urea as there are hundredths of a milligram of 'Albuminoid Ammonia' persisting in each measure."*

5 As already stated, do not observe the tint of a "Nesslerized" solution until five minutes after the addition of the reagent. After the expiration of that time the color may be considered constant; no further material change taking place in twelve hours. Consequently in the case of the examination of many successive samples, the "Nesslerized" standard solutions need not be made up for each water, but those prepared in the morning may be used during the entire day, proper care being taken to protect them from the action of the atmosphere by covering them when not in use.

6 Water samples will not keep many days;

* It must be noted, however, that Dr. Smart allows *twenty* minutes for the filling of a 50 c. c. "Nessler" jar.

whence the necessity for a speedy analysis after the collection is once made. The changes which take place in water upon keeping, have been carefully investigated by Smart and Mallet (*Nat. Board Health, 1882*), and, although their opinions upon this topic are not so full as the rest of their work, they are nevertheless very convincing.

Investigations tending in the same direction and leading towards the same results were also undertaken in this laboratory before Mallet's report appeared.

The tendency is for "Free Ammonia" to disappear upon keeping: and, as a rule, the "Albuminoid Ammonia" also diminishes. From observations made upon the appearance and disappearance of nitrites, there seems to be little doubt but that the loss of "Free Ammonia" is to be accounted for by a process of nitrification. Nitrites are formed at the expense of the ammonia, and they, in their turn, are converted into nitrates by further oxidation. Nitrogenous organic matter in water may be considered as belonging to two classes: *First*, "That which passes readily into the condition of 'Free Ammonia' through putrefactive agencies," and which is consequently easily acted upon by the permanganate solution; and, *second*, that which is more stable, and from which no ammonia is evolved during distillation with the above reagent. Upon standing for any considerable time, this latter class becomes slowly converted into the less stable variety, which in its turn is gradually converted into "Free Ammonia," the ammonia in turn becoming finally nitrified as

already stated. Thus we have a perfect system of changes, from the stable nitrogenous organic matter on the one hand, to the fully oxidized nitrate on the other. Of course, we are citing but a typical case, and must be prepared to see all manner of departures therefrom in special instances, according as the character and amount of materials, and the nature of the environment may differ.

It is different to lay down any fixed time beyond which the integrity of the water sample should be suspected, as each individual case must be governed by its own set of circumstances, but, in general, ten days should be looked upon as the extreme limit.

Oxygen Consuming Capacity.

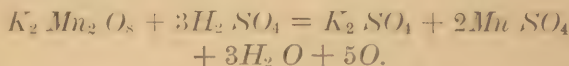
“Required Oxygen.”

The third and last method for estimation of organic matter that we shall touch upon, is Kubel's modification of the old permanganate process of Forchhammer. The original mode of procedure was published in 1850 and “consisted merely in adding a solution of potassic permanganate of known strength, without any other reagent, to a measured amount of water to be examined, until the liquid had acquired a faint permanent tinge, and then noting the quantity used. It was afterwards ascertained that more uniform results could be obtained, and with less expenditure of time, by causing the permanganate to act in the presence of

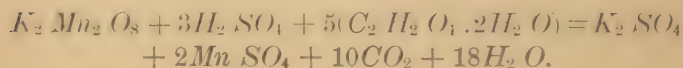
free acid or free alkali." Kubel uses a boiling temperature.

The form of determination recommended by the committee is that employed by Dr. Smart. The necessary solutions are :

Standard Potassium Permanganate Solution :—Dissolve 0.3952 gram of the salt in one litre of distilled water. Each *c. c.* of such solution will contain 0.1 *m. g.* of oxygen available for oxidation. The available oxygen of the permanganate in presence of sulphuric acid may be represented by the equation



Solution of Oxalic Acid [$H_2 C_2 O_4 . 2H_2 O$] :—Dissolve 0.7875 gram of the crystallized acid in one litre of distilled water. This solution if titrated against the permanganate solution (while hot, and in presence of $H_2 SO_4$) will correspond to it *c. c.* for *c. c.* The equation is



Dilute Sulphuric Acid :—One part of the strong acid to three of distilled water.

Determination :—Place 200 *c. c.* of the water under examination in a 400 *c. c.* flask ; add 10 *c. c.* of the dilute sulphuric acid, and run in the standard permanganate solution, from a burette, until the water has a very marked red color. Boil *ten*

minutes, adding more permanganate from the burette from time to time, if necessary, in order to maintain the intensity of red color observed at the start. Do not let the color fade nearly out, and then add the permanganate in quantity, at once, but strive to keep the color as nearly constant as possible by gradual addition.

Remove the flask from the lamp, add 10 c. c. (or more, if necessary) of the oxalic acid solution to destroy the color, and then add the permanganate solution from the burette until a faint pink tinge again appears. From the total permanganate used, deduct that corresponding to the 10 c. c. oxalic acid employed, and from the remainder calculate the milligrams of "available oxygen" consumed by the organic matter present in the water. Correction must be made for nitrites, ferrous salts, or hydrogen sulphide if any of them be present.

Standards :—

Leeds' for *American Rivers*. . . 5,000 to 7,000

Averages from determinations by Dr. Smart :—

Impure (14 samples)	5.880
Doubtful purity (5 samples)	3.073
Medium purity (15 samples)	1.414
Pure (18 samples)	0.581

All former determinations in this laboratory having been made according to the "*Tidy*" method, it would be useless to quote the average results.

Lead and Copper.

It at times becomes necessary to examine water for these poisonous metals, and the ease with which their dark sulphides may be formed, provides a ready method.—(Miller.)

Prepare a standard solution of lead acetate (sugar of lead) $Pb(C_2H_3O_2)_2$.34*g.* by dissolving 1.8309 grams of the salt in one litre of distilled water. Each *c. c.* will contain 1 *m. g.* metallic lead.

Pour half a litre of the water into a large porcelain dish, add two or three drops of strong *HCl*, and stir with a glass rod moistened with ammonium sulphide. Should a dark tint be produced, fill a 100 *c. c.* "Nessler" jar from the contents of the dish and match the tint by operating with measured amounts of the standard lead solution diluted to 100 *c. c.*

This will not, of course, distinguish between copper and lead, but, inasmuch as each is objectionable, distinguishing is really not necessary.

In order to test the action of the water upon *lead pipe*, permit it to remain in contact with both bright and dull lead (in separate vessels) for twenty-four hours, and then examine the water as above.

Method of stating results as recommended by the committee :

All the results are to be stated in parts per million

milligrams per litre, and in the manner shown below :

Total solids	
Chlorine	
Nitrogen expelled as ammonia on boiling with Na_2CO_3	
equals "free ammonia"	
Nitrogen expelled as ammonia only on boil- ing with alkaline permanganate	
equals "albuminoid ammonia"	
Nitrogen as nitrite	
Nitrogen as nitrate	
Organic matter (in terms of milligrams of oxygen consumed by one million of water)	
Hardness	
Etc.	

The Kjeldahl Method.*

"It is the hope of the committee that many trials will be made of Drown and Martin's application of the Kjeldahl nitrogen method in the sanitary examination of water; the results of the experience therewith would be useful to us in any further consideration of this matter."

Place 500 *c. c.* of the water in a round-bottomed flask and distill off 200 *c. c.* (This distillate may be utilized to determine "*free ammonia*.") Cool the

* For full report on this method see *Journal Analytical Chemistry*, vol. 3, page 258.

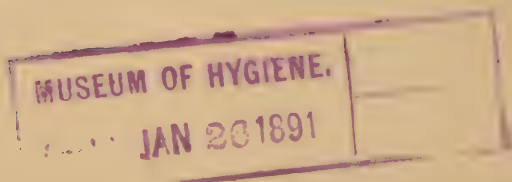
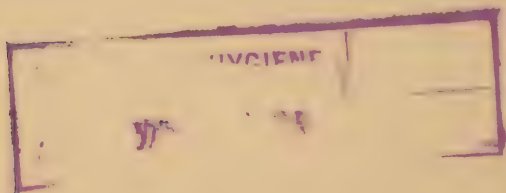
residue and add 10 *c. c.* concentrated H_2SO_4 . Disconnect the condenser and boil until nearly all the water is driven off and the residual acid is white or pale yellow.

Add a little powdered potassic permanganate, until the liquid acquires a green color. Cool.

Add 200 *c. c.* *pure* water washing down all acid from the neck of the flask.

Add 100 *c. c.* sodium hydrate solution.* Distill slowly, catching the distillate in very dilute hydrochloric acid, until about half the bulk of the liquid has passed over. Dilute the distillate to 250 *c. c.* with *pure* water; mix, and take 50 *c. c.* for "Nesslerization."

*The sodium hydrate solution is made by dissolving 200 grams of commercial caustic soda of good quality in 1.25 litres of distilled water, adding 2 grams of potassium permanganate, and boiling down to somewhat less than a litre. When cold the solution is made up to a litre.



APPENDIX.

NOTE 1. "The question of a standard by which to judge the quality of any particular sample of water has frequently been discussed, but as yet no generally satisfactory conclusion has been arrived at. Several standards have indeed been proposed, but none has been generally adopted, and we cannot say that we regret the result. The laying down of any one general standard by which to judge the great variety of waters met with in different parts of the country and in different geological formations is, in our opinion, at once impossible and undesirable.

By all means take into consideration and, on suitable occasions, make use of such general standards as have been laid down by chemists of high ability and large experience; but use these standards cautiously and with discrimination, and judge every case on its own merits. Judge by its conformity to, or divergence from, the general character of the waters of the district from which it comes; in other words, have district standards instead of a general standard."—(A. Dupré "Analyst," April, 1883.)

NOTE 2. In an article by Dr. H. B. Baker, printed in the *report of the Michigan State Board of Health for 1884*, the relation between the lowness of water in wells and the prevalence of typhoid fever is fully discussed. The author accounts for what statistics show to be an

undoubted fact, by pointing out that as the level of the well water sinks below the level of the neighboring cesspools and other vaults of contamination, the ever widening inverted cone of drainage (whose apex is the surface of the water in the well) embraces ever more and more sources of pollution. The interesting fact is also touched upon in the same article, that such a specific disease as typhoid fever has been developed by the use of water in which organic matter was putrefying, but which was not contaminated with dejections from typhoid fever patients: *e. g.* rotten turnips caused it in one instance, and a decomposing turtle in another.

NOTE 3. "We cannot expect to find the effect of impure water always sudden and violent. The results of continued imbibition of polluted water are indeed often gradual and may elude ordinary observation, yet be not the less real and appreciable by close inquiry. In fact it is only when striking and violent effects are produced that public attention is arrested; the minor and more insidious, but not less certain evils, are borne with the indifference and apathy of custom."—[*Water, Air and Food:—Fox.*]

NOTE 4. Peaty water is always to be considered as of inferior grade, not to be employed for public supply unless clear water be unobtainable. Such a water is liable to induce diarrhoea in persons unaccustomed to its use. Finely divided iron-rust, due to intermittent transmission through iron pipes, will also produce the same result.

